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Volume 21 January, 1935 *Number 1*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

21
1935

THIS ISSUE

Bus Operation and Maintenance

Lubrication of Component Units

PUBLISHED BY
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TEXACO PETROLEUM PRODUCTS

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Published by
The Texas Company, 135 East 42nd Street, New York City
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Vol. XXI January, 1935 No. 1

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Bus Operation and Maintenance

Lubrication of Component Units

THE NEW YORK
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ASTOR, LENOX AND
TILDEN FOUNDATIONS
1936

DURING the past decade the bus industry has established itself firmly as a most necessary part of the nation's transportation system. The bus industry underwent its "acid test" during the recent business depression and the manner in which it came through is sufficient evidence that the bus is here to stay and play its part in the transportation business.

Prior to the depression we had a period of great prosperity which included as part of its cause and effect the greatest road-building program the world has ever seen. With improved roads the bus industry made great strides by being able to speed up its service and at the same time materially reduce the wear and tear formerly imposed on almost all parts of the vehicle. During this period more progress has been made in the refining of petroleum products than in all the previous years in the industry's history.

No other industry depends on petroleum products for its success so much as the bus industry and this fact accounts for the close relation existing between these two industries. Purchases of petroleum products represent approximately one-half of the total operating and maintenance expense of the average bus company; therefore, it is obvious that the right types of fuel and lubricants play a very important part in the success of this comparatively new industry.

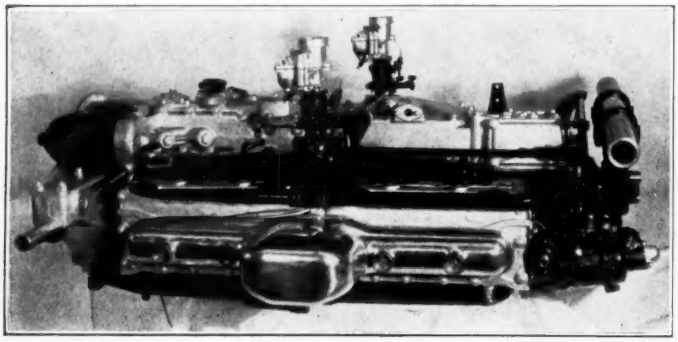
This has led to exhaustive research work and road tests in conjunction with bus operators. The petroleum industry has also cooperated very closely with manufacturers of bus equipment by producing fuels and lubricants suitable for the exceptionally severe conditions encountered in actual service.

In the early stage of the bus industry, the bus operator converted truck chassis by simply adding bus bodies to same. It was soon discovered that the service in the bus field was much more severe and this converted equipment proved unsatisfactory. With the cooperation of bus operators a number of firms made studies of the requirements of the bus field and by constant improvements have created a highly specialized and satisfactory vehicle.

Although most manufacturers of buses are also producing motor trucks, there is a distinct difference in the problems which are encountered in the bus industry and this is recognized by the fact that separate departments handle all matters pertaining to the engineering, servicing and even marketing of buses.

Manufacturers of petroleum products, likewise, handle the bus business through separate departments and have staffs of lubricating engineers specially trained to the needs of the bus industry. These experts co-operate with the maintenance departments of the bus

companies and assist them with problems of all kinds. The function of the maintenance department of any bus company is of the utmost importance, and it is in these departments where some of the most brilliant and resourceful men of the industry can be found.



Courtesy of The White Company

Fig. 1—Showing the new 12-cylinder White Pancake engine. This is a horizontally opposed design, which is attained by opening the angle of a V-type engine so that the two banks of cylinders containing six each are horizontally opposed. The engine is located underneath the floor of the bus.

Good garage and shop facilities are of vital importance to the maintenance department in order to efficiently maintain a bus fleet in the best possible condition and at the lowest possible cost. Ample storage capacities for petroleum products, and, preferably, railroad siding facilities are also desirable so that purchases can be made in quantities and benefits can be derived by the reduction in prices allowed for such purchases.

EFFECTIVE LUBRICATION ESSENTIAL

Effective lubrication is most essential to a modern bus maintenance program. It is equally important to the operating department. Effective lubrication permits a company to operate with a minimum of stand-by equipment. It prevents unnecessary time losses, expensive replacement of parts and road failures. Effective lubrication insures service without interruption and thereby safeguards the operator's reputation.

The problem of effective lubrication is fully recognized by the bus industry. Bus lubricants and the method of their application are factors closely allied to operating economy and reliability. Unsuitable lubricants result in extensive wear, carbon deposits, loss of power, excessive consumption, high maintenance costs and unnecessary breakdowns—all of which defeat the very purpose of efficient bus operation.

Lubrication of the Engine

Gasoline engines will function most satisfactorily and have longer periods of useful life when effectively lubricated. To the credit of builders of automotive engines it must be said that this factor is fully recognized. Simplicity of design and ready access to all parts of the engine have been accepted as fundamental requirements by builders of modern automotive engines.

While the average cost to lubricate an engine is comparatively small, this cost can very quickly be increased beyond all reason by the use of an unsuitable grade of lubricating oil which will not afford the necessary protection and result in abnormal wear and increased maintenance costs.

Function of Piston Rings

To attain maximum output from an engine, one of the most important factors is the proper functioning of the piston rings. The purpose of piston rings is to prevent loss of compression, blow-by of combustible fuel vapors and pumping of lubricating oil into the combustion chamber.

To insure the greatest degree of ring seal the rings must be able to expand readily in the piston grooves and follow the cylinder bore at all speeds and under varying temperatures. As a result, the bore should be smooth and absolutely cylindrical, otherwise the rings may wear excessively in the piston grooves. Such wear will lead to ultimate impairment of the seal.

While a close fit of the piston rings is essential, it is important that the rings shall not bind under any operating conditions. This must be given special consideration in warm weather, where engine temperatures are increased and the viscosity of the oil film proportionately reduced. Otherwise the value of the piston rings as a sealing medium may be affected.

Piston rings furthermore compensate for any irregularities in clearance due to wear, thus preventing sticking or seizing of the pistons under the relatively high temperatures of operation. Sluggish piston rings due to accumulation of hard carbon deposits in the piston ring grooves will immediately cause power and compression losses.

Lubricating oil in the combustion chamber will result in excessive consumption and an accumulation of carbonaceous deposits on the spark plugs, piston heads and within the combustion chamber, to materially reduce power output. Also, this will cause the engine to knock under certain conditions of overload.

Piston Ring Installation

Piston rings, however, can only function dependably provided that they are properly fitted, carefully installed, effectively lubricated and kept free from deposits which might affect their flexibility. Free movement is of most decided importance, as sticking or any reduction in ability to flex may lead to oil pumping or blow-by.

Fitting and installation are, of course, mechanical matters. In a new engine, or one which is functioning on its original rings, it is fair to assume that the installation as made by the builder has been correct. Where rings are to be renewed, however, all work connected therewith should be properly supervised.

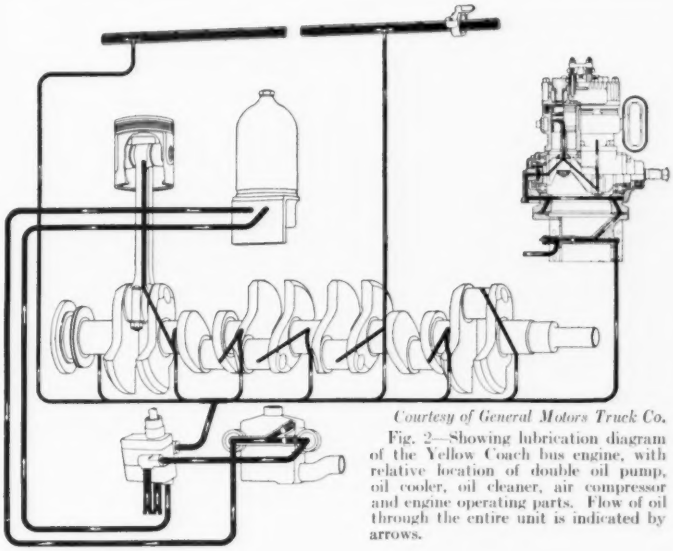
From this point on the problem is virtually to prevent accumulation of deposits around or in back of the rings which would tend to cause them to become stuck in the piston grooves, or to fail to flex and seal properly. Development and maintenance of an adequate film of oil on the cylinder walls and ring surfaces can be entirely relied upon in an engine unless the lubricating system is functioning improperly. Temperatures, however, especially at the top of the stroke, will be comparatively high. With certain grades of motor oils these will be sufficient to cause more or less decomposition, with resultant development of gummy residual matter. There will always be possibility of such matter working into the ring grooves, to subsequently impair the operation of the rings. When this occurs, engine efficiency and lubrication economy will commence to drop off, being reduced more and more as the rings continue to fail in their intended duty.

Grade of Oil a Factor

If piston rings are to expand and contract readily in the piston ring grooves, it is essential that a high grade of motor oil is used. The motor oil should leave a minimum of carbon residue, so as not to impede free movement of the rings. The use of the proper grade of motor oil commensurate with climatic conditions, will be insurance against stuck piston rings, for the amount of carbon deposit will be so small that there will be but little possibility of carbon accumulation behind the piston rings. It is interesting to note that where heavy carbonization occurs a piston ring will act as a reamer and cut the polished surfaces of the cylinder bore and the increased clearance between the piston and the cylinder bore will result in passage of an excessive amount of motor oil into the combustion chamber. Dilution of the motor oil by blow-by of combustible vapors will also occur.

Bearings

Bearings also occupy a position of prominence in modern automotive bus engine operation. The most important factor in satisfactory bearing performance is that bearings are suitably fitted and have proper clearance to permit ready circulation of the motor oil. If bearings are fitted too tightly the motor oil cannot penetrate between the contact surfaces of the rotating elements; this will result in heat generation, with the possibility of burned out bearings. Excessive clearances in bearings will result in failure due to hammering-out and crystallization of the bearing metal.



Courtesy of General Motors Truck Co.

Fig. 2—Showing lubrication diagram of the Yellow Coach bus engine, with relative location of double oil pump, oil cooler, oil cleaner, air compressor and engine operating parts. Flow of oil through the entire unit is indicated by arrows.

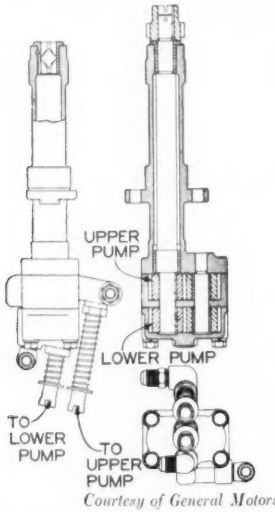
In accordance with the theory and practice of lubrication it has been developed that an adequate film of oil between any two surfaces to be lubricated will effectively prevent wear of the respective moving parts, provided that film is continuously maintained during operation. Where it is impossible to maintain a suitable film of oil due to ineffective means of lubrication, or road dust or other foreign matter gaining entry into the engine and becoming absorbed by the lubricating oil, wear will occur between the rotating or reciprocating parts regardless of the original purity or characteristic of the motor oil.

Research has indicated that the presence of abrasives such as road dust, hard carbon, etc., is responsible for the majority of all engine wear. Manufacturers of buses realize the importance of this fact and provide oil and air filters on their engines. Bus operators in turn have adopted regular periodical schedules on oil and air filter maintenance depending on the

type of service as well as the geographic location in which the buses operate.

Crankcase Temperature Control

Control of crankcase oil temperatures on many bus engines within a certain range has been accomplished by application of oil temperature regulators. These devices consist of a small radiator enclosed in a metal housing, connecting both the circulating water and oil systems.



Courtesy of General Motors Truck Co.

Fig. 3—Section and outline views of the oil pump as installed on the Yellow Coach Bus engine. This unit is of special dual construction having two sets of gears enclosed in separate housings. The lower gears force oil through filter and temperature regulator, the upper gears forcing it to the engine bearings.

Lubricating oil and water flow through separate passages at right angles to each other, being kept apart by thin copper walls of high heat conductivity. As the lubricating oil passes through the temperature regulator, the water of the engine cooling system raises or lowers the temperature of the oil, as conditions require. This continuous transfer of heat equalizes oil and water tempertures to within very close limits. To keep the oil temperature regulators operating at their maximum efficiency, it is necessary to clean them out at regular intervals.

THE TRANSMISSION AND DIFFERENTIAL OR REAR END DRIVE

Transmission and differential construction in the modern bus is similar to that of the modern passenger or commercial vehicle. Essentially the purpose of the transmission is to enable the operator to select such speed or gear ratios between the engine and the rear axle as will best meet various conditions in traffic and on the open roadway, by the mere manipulation of a lever.

The differential or rear axle drive, likewise involves an arrangement of gears. The differential is common to all types of such vehicles. Essentially this will involve worm or bevel gears according to the design of the drive. The object of the differential is a dual one, viz.:

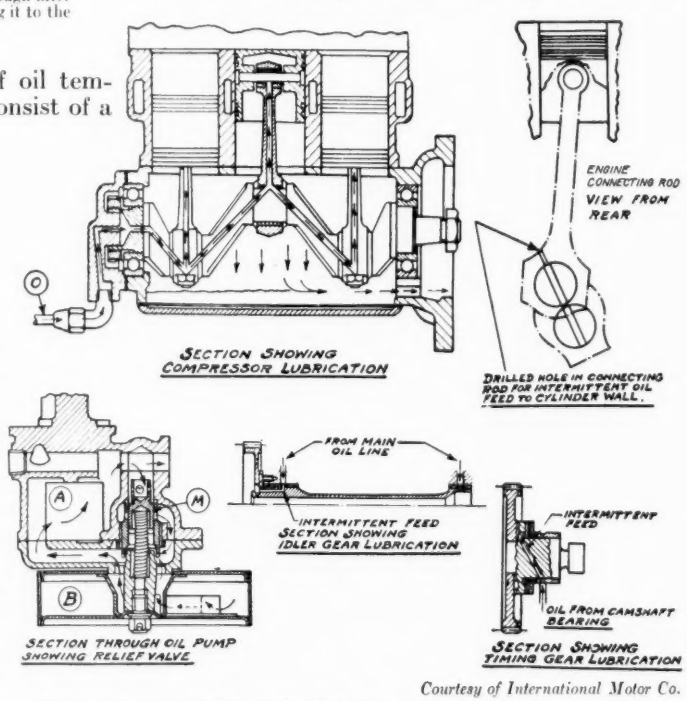
(a) To transmit power from the engine to the rear axle, and

(b) To enable the rear wheels to rotate at different speeds, as is necessary when the bus is turning corners or operating in any other than a straight line.

Both worm and bevel gear drives are used in the bus industry. Each is rugged, simple of design, relatively silent and capable of effectively meeting the usual heavy duty involved.

Whatever the type of drive, by virtue of its construction, the lubrication of the transmission and rear axle in general will involve two distinct problems; first, the lubrication of the gears, or worm, and second, the lubrication of the shaft bearings.

Inasmuch as the one lubricant must, as a rule, serve both gears and bearings, it must be of sufficient viscosity to not only maintain the requisite film of lubricant on the gear teeth, but also to have adequate penetrative ability to serve the bearings whatever their type of design.


ENGINE CONNECTING ROD VIEW FROM REAR
SECTION SHOWING COMPRESSOR LUBRICATION
DRILLED HOLE IN CONNECTING ROD FOR INTERMITTENT OIL FEED TO CYLINDER WALL.
FROM MAIN OIL LINE
INTERMITTENT FEED SECTION SHOWING IDLER GEAR LUBRICATION
INTERMITTENT FEED
OIL FROM CAMSHAFT BEARING
SECTION THROUGH OIL PUMP SHOWING RELIEF VALVE
SECTION SHOWING TIMING GEAR LUBRICATION
A
B
M
O

Courtesy of International Motor Co.

Fig. 4—Lubrication details of the Mack bus engine air compressor, timing gear, idler gear, engine connecting rod and oil pump. (A) is the main oil pump; (B) the oil screen which is removable with oil pump from bottom of engine; (M) Oil pump pressure relief valve and (O) The oil pipe leading from crankcase to air compressor.

LUBRICATION

The principal function of a gear lubricant is to provide a cushioning film between the gear teeth, thereby reducing the shock of impact between the teeth and preventing scuffing of the contact surfaces. Constant improvements in gear design, metallurgy, accuracy of gear manufacture and in heat-treating methods have been made during recent years to compensate for the increased horsepower and driving speeds.

It is of great importance that bus transmissions and differentials be able to withstand the severe operating conditions which usually prevail, without attention, for considerable periods of time. For this reason all such parts as shafts, bearings and the gears are made extra large, thereby safeguarding these units against possible overload and excessive gear-tooth pressure, factors which would result in abnormal wear and noisy operation.

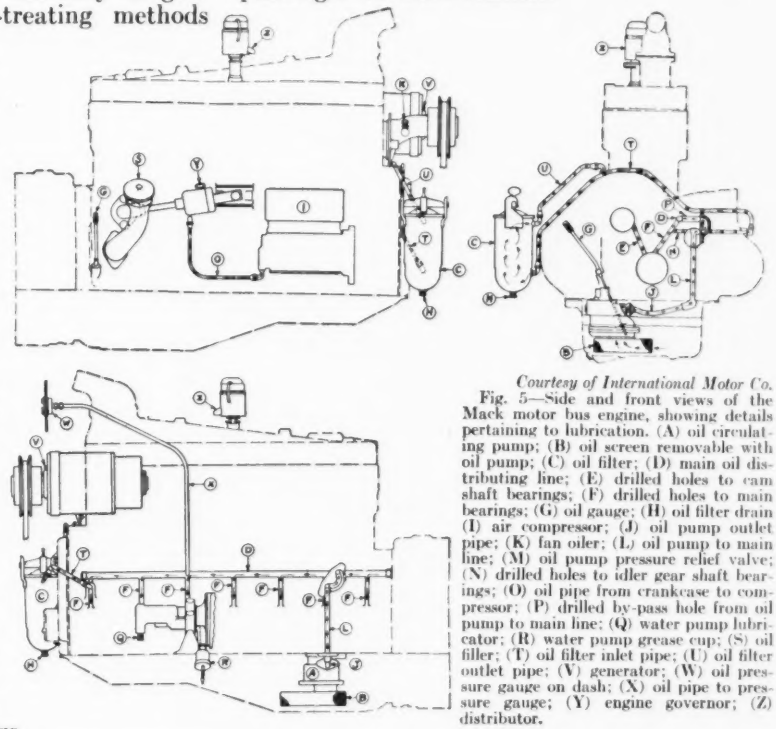
Bus manufacturers also provide for an unusually large supply of gear lubricant in the transmission and differential to eliminate the necessity for frequent fillings.

The cost and amount of lubricant required for the transmission and differential is comparatively small. On the other hand, its function is extremely important. For this reason most careful attention should be given to the selection of any such product. Absolute protection of both gears and bearings must be assured to prevent abnormal wear and increased maintenance costs which would be caused by an inferior lubricant.

Good gear lubricants for motor bus use should contain no inorganic fillers such as talc, mica, graphite or asbestos, which would become lapping agents. The lubricant should resist separation, be non-abrasive, non-corrosive, have minimum tendency towards oxidation and resist air entrainment and expansion. It also must have good adhesive qualities and must not channel under normally low temperatures.

CHASSIS PARTS—LUBRICATION AND MAINTENANCE

Moving parts on the chassis include the spring shackle bolts, the steering mechanism, the universal joints, the wheel bearings, the propeller shaft bearings, and the shock absorbers or air springs. It is fitting to discuss these in detail from the viewpoint of their construction and principles of operation, in order that their lubricating requirements may be better understood and their importance to passenger comfort realized.



Courtesy of International Motor Co.

Fig. 5—Side and front views of the Mack motor bus engine, showing details pertaining to lubrication. (A) oil circulating pump; (B) oil screen removable with oil pump; (C) oil filter; (D) main oil distributing line; (E) drilled holes to cam shaft bearings; (F) drilled holes to main bearings; (G) oil gauge; (H) oil filter drain (I) air compressor; (J) oil pump outlet pipe; (K) fan oiler; (L) oil pump to main line; (M) oil pump pressure relief valve; (N) drilled holes to idler gear shaft bearings; (O) oil pipe from crankcase to compressor; (P) drilled by-pass hole from oil pump to main line; (Q) water pump lubricator; (R) water pump grease cup; (S) oil filler; (T) oil filter inlet pipe; (U) oil filter outlet pipe; (V) generator; (W) oil pressure gauge on dash; (X) oil pipe to pressure gauge; (Y) engine governor; (Z) distributor.

All these parts are exposed to the elements at all times and any protection from abrasive dirt, water, etc., must come from the lubricant within these bearings. The lubricant does this by forming a seal around such places exposed to the elements and preventing abrasives and moisture from reaching the bearing itself.

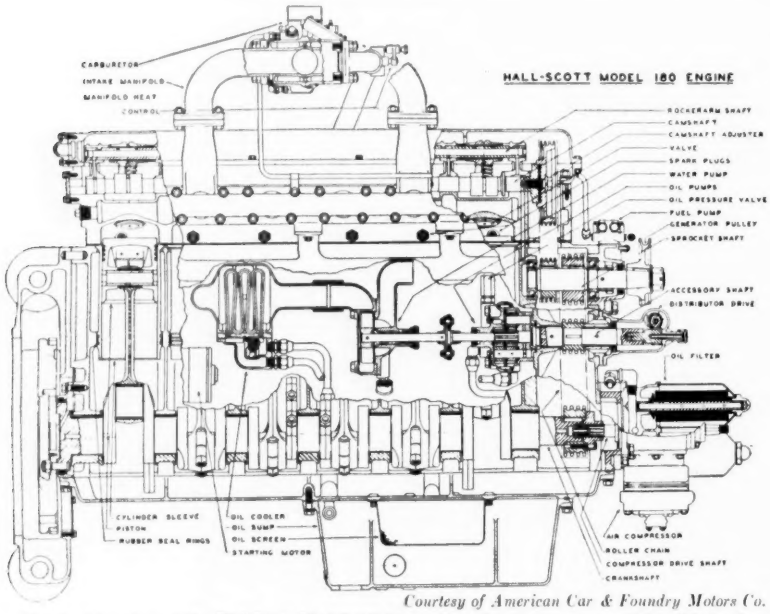
A lubricant for this service must, therefore, have good adhesive qualities and also resist wheel wash, to a maximum degree.

To insure easy steering and riding comfort, the lubricant should have a high degree of oiliness. Efficient lubrication on these chassis parts eliminates excessive wear and clearances and prevents the chassis from becoming noisy. Well lubricated spring shackles permit free movement of the springs and prevents transmission of the road shocks to the body of the bus, thereby increasing the passenger's comfort as well as saving the body of the bus from becoming loose and rattling.

It is, therefore, of the utmost importance to the maintenance department that a chassis lubricant is used which will give the proper protection to these exposed parts and prevent them from becoming the cause of ruining the vehicle as a public carrier.

Spring Shackle Connections

While certain builders make use of a rubber pad or connection to eliminate the necessity for shackle connections and consequently lubrication at these points, the majority of buses use the typical shackle pin or bolt connection in a one-piece bearing to take care of the play which occurs between the frame and spring members.



Courtesy of American Car & Foundry Motors Co.

Fig. 6—Line view of the Hall-Scott Model 180 bus engine, showing parts essential to lubrication.

Spring connections by reason of the fact that they are frequently lubricated while carrying the weight of the body may not receive lubricant throughout their bearing surfaces.

To aid in effective distribution of the lubricant and the maintenance of an adequate lubricating film between the pin and bearing, the former is drilled part way along its axis. From the inner end of this hole another is drilled at right angles thereto, to permit of passage of lubricant to the bearing surface. The lubricating fitting is installed in the outer end of the shackle pin or bolt, being screwed into the hole which has been suitably tapped for this purpose.

The Steering Mechanism

The steering mechanism includes knuckles, rods, and the reduction gearing of the steering post. Careful attention to the lubrication of rods and knuckles with the proper grade of oil or grease, according to the type of lubricating system, will make the machine steer far more easily, promote more comfortable riding, and render driving a far less tiring task to the operator.

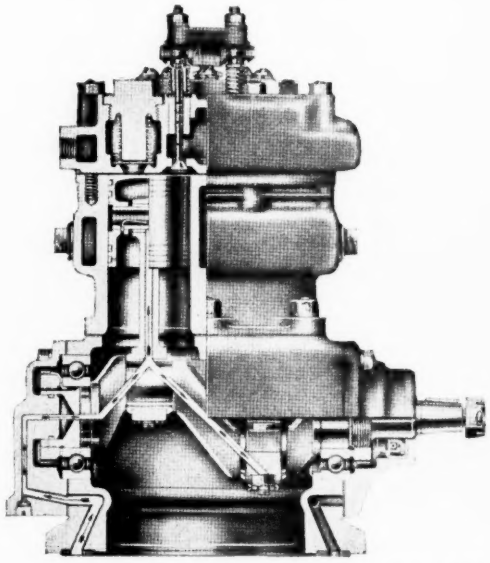
Likewise the lubrication of the steering gear with the right grade of lubricant will do away with that "stiff" movement of the wheel, reduce the occurrence of play and give far better driving control.

Universal Joints

Universal joints used in the modern motor bus are of the grease or oil type, the latter coming more into prominence during this past year.

Lubrication of the grease type joint involves the problem of a lubricant which must have unusual adhesive and cohesive qualities to withstand the centrifugal force in these joints without being thrown out, and at the same time possess a high degree of oiliness to lubricate effectively the contact surfaces of the driving pins in the universal joints.

Failure to lubricate these contact surfaces properly results not only in the destruction of the driving pin bearings but also it may prevent the full power of the engine from being transmitted to the rear axle; this will of course lead to a reduction in gasoline and oil economy.



Courtesy of Bendix-Westinghouse Automotive Air Brake Co.

Fig. 7—Details of the Bendix-Westinghouse UVW compressor showing details of the lubricating system.

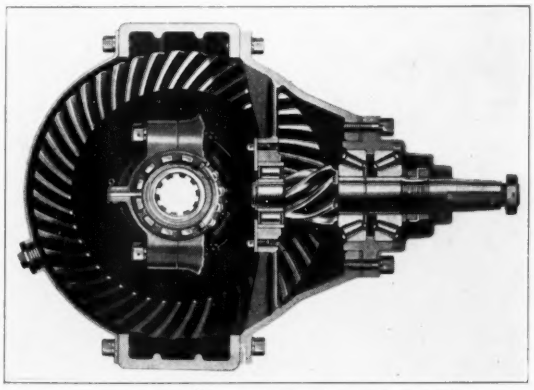
The oil type universal joint is designed for oil lubrication and grease should never be used in these joints under any circumstances. Oil type universal joints used in modern motor bus design are provided with fittings for pressure lubrication in the trunnion cross, through which the oil leads to all four oil reservoirs and from there is fed through a small hole directly to the bearing.

Propeller Shaft or Steady Bearings

The purpose of such bearings is to carry the propeller shaft and maintain it in proper alignment. This shaft serves as the means of transmitting the power from the engine, via the clutch and transmission or speed change mechanism, to the rear axle and wheels. On account of the relative location of the engine with respect to the rear axle, and because of a certain amount of possible distortion, the propeller shaft is usually connected through suitable universal joints.

In view of the fact that considerable power losses may accrue should the propeller shaft fail to function properly, every care should be given to its bearings and especially to their lubrication. These latter are essentially a part of the chassis and as such should be inspected and re-lubricated periodically.

The same lubricant as recommended for other chassis parts should insure continued and efficient service, provided, of course, that the bearings are properly installed and maintained in a clean condition. This latter will be practically assured when the right lubricant is used under adequate pressure.

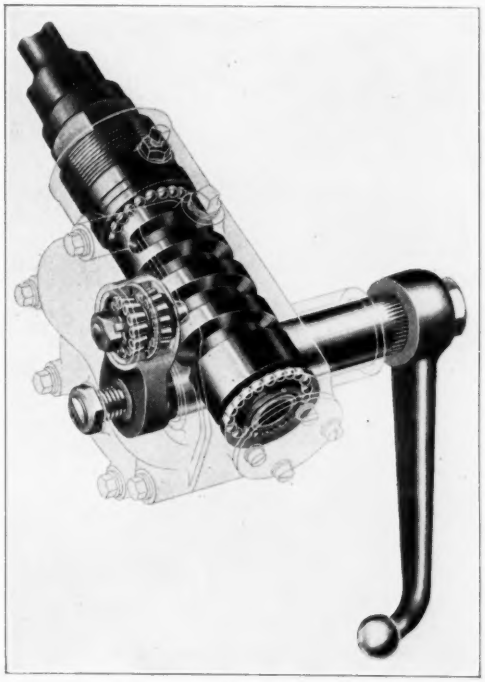


Courtesy of The Timken-Detroit Axle Company

Fig. 8—Showing vertical cross section through the Timken bevelled gear drive.

Wheel Bearings

Motor buses are universally equipped with wheel bearings of the roller type. The lubrication of these bearings would be comparatively simple were it not for the fact that over-lubrication results in the lubricant coming in contact with the brake shoes and thereby causing defective brake action. On the other hand lack of lubrication will result in destruction of the bearings with subsequent road failures and



Courtesy of Ross Gear & Tool Company

Fig. 9—Showing the Ross roller mounted type steering gear, which is widely used in motor bus operation. The relative location of the ball and roller bearings used in this assembly is plainly shown.

unnecessary loss of time and money. It was, therefore, up to the maintenance departments of the bus industry to work out a schedule of lubrication of wheel bearings that would safeguard against over-lubrication as well as under-lubrication. Experience has taught them that the brake mechanism requires certain periodical inspections which necessitate removal of the wheels, and it was decided that this would be the ideal time to lubricate the wheel bearings.

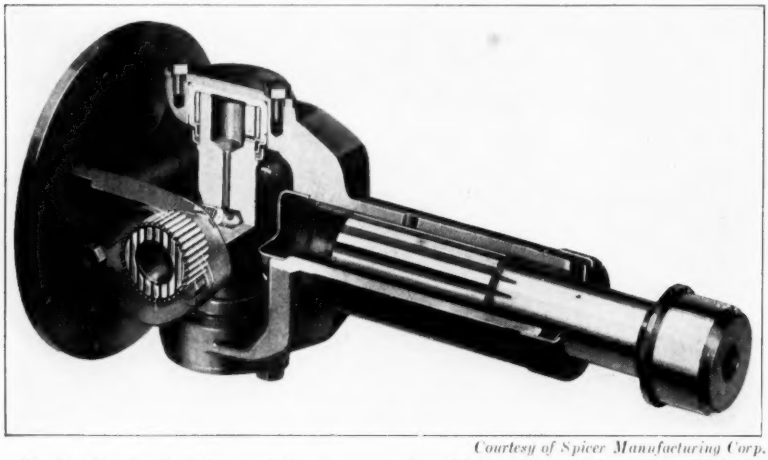
In this way the lubrication of the wheel bearings can be accomplished by hand-packing, and by this method the correct amount of lubricant is applied, eliminating both over- and under-lubrication. This method of lubrication has been universally adopted by all the leading bus companies.

Great care should be used in the selection of the proper lubricant. Such a product for wheel bearings in motor bus service should have good chemical stability, good adhesive qualities, furnish a fluid film between the contact surfaces of the bearings, and at the same time seal this film within the bearings at the outside of the bearing race. The lubricant should have a melting point high enough to prevent leak-

age into the brake-shoes, and must not channel under normally low temperatures.

The lubricant must not be affected by the wheel wash and it must seal the wheel hubs against ingress of abrasive road-dirt and water.

From the foregoing it is obvious that, aside from the lubricating of the wheel bearings themselves, a number of other important functions have to be performed by this lubricant. Bus manufacturers recognized this fact to be of such vital importance that specific recommendations as to what lubricant should be used are issued to their customers.



Courtesy of Spicer Manufacturing Corp.

Fig. 10—Showing the Spicer needle-bearing type universal joint, with means for sealing, oil inlet for needle bearing and spline shaft assembly, relief valve and oil passages.

Brake Connections

Mechanical brake connections, such as hanger bearings, etc., involve perhaps more simple mechanisms than many other chassis parts. On the other hand they are among the most important operating parts on the modern motor bus.

The potential hazards that may accrue in the event of brakes not functioning instantaneously or releasing promptly are so serious that every effort should be made to protect them effectively by proper lubrication.

Brake connections are exposed to more or less dust and the effects of the weather. There will, therefore, be considerable likelihood of rusting and abnormal wear occurring if they are not kept supplied with an adequate film of oil or grease, which has sufficient adhesive ability to "stay put" and not drip or throw off.

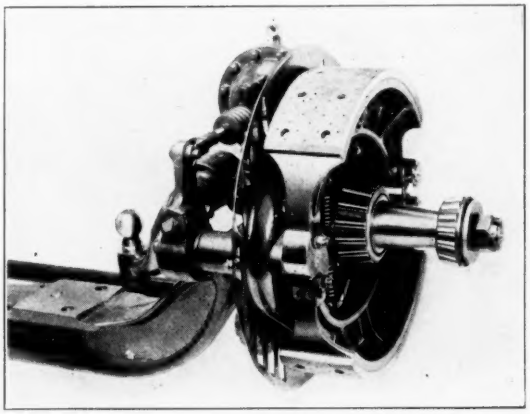
Pressure lubrication is a most effective method of protecting hanger bearings by preventing the entry of water, dust and dirt.

EVALUATION OF LUBRICATING ABILITY

Lubricating ability of any petroleum product is dependent upon the thoroughness of the refining process. This, in turn, is controlled by certain physical and chemical properties which must be studied with regard to the expected operating conditions to which the lubricant will be subjected. The bus operator must be thoroughly conversant with these properties in order that he may be able to intelligently select oils and greases best suited to his particular operating conditions. When dealing with motor oils, the viscosity, carbon residue content, and flash point should be of chief concern. Greases, in turn, require consideration of resistance to contamination and breakdown, and their consistency or body, the latter serving as a guide as to ease of handling by pressure gun, and ability to resist bearing pressures and road shocks.

The Significance of Viscosity*

The viscosity test has proved of value as a means of determining the physical ability of a lubricating oil to maintain lubrication under any set conditions of operating pressure and temperature. It is of distinct importance to have a clear understanding of this test, in view of the relation of fluid or internal friction to power consumption. Obviously, reduction of fluid friction will lead to proportional reduction in power consumption.



Courtesy of The White Company

Fig. 11—Showing White standard front axle assembly and relative location of wheel bearings to brake connections.

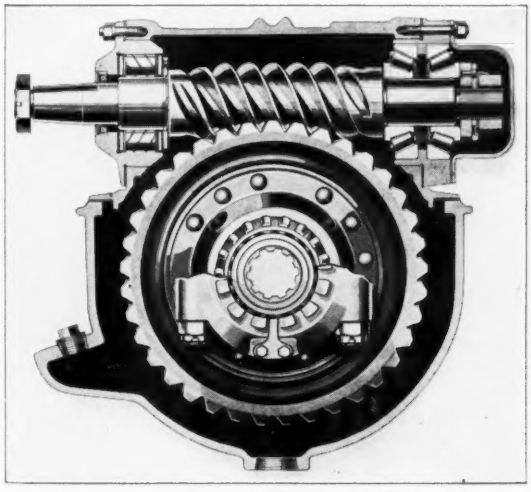
Viscosity or body of an oil, as it is more generally understood by the average operator,

* For further information relative to viscosity, carbon residue and especially the interpretation of the flash and fire tests see "The Significance of Tests of Petroleum Products," Published by American Society for Testing Materials, 1934 edition.

is a measure of the relative fluidity at the temperature of observation. It can also be regarded as that inherent property by virtue of which flow is retarded, due to the resistance which the particles or molecules of an oil will offer to one another as they come in contact in circulation through the lubricating system or between the moving parts of a machine. It is possessed by all lubricating oils to a varying degree, according to their extent of refinement. Viscosity will vary inversely with temperature, i.e., the colder an oil the heavier or more sluggish will it become. In contrast, as the temperature is raised, the same oil will become more and more fluid.

Viscosity is measured by observing the time required for a predetermined quantity of oil, i.e., 60 cc., to flow through an orifice of standard size under standard temperature conditions. The Saybolt Universal Viscosimeter as adopted for this purpose by the American Society for Testing Materials is used for motor oils, the standard temperatures of test being 100, 130 and 210 degrees Fahr.

In normal laboratory practice 100 degrees Fahr., is standard for the Saybolt machine when dealing with distilled or blended lubricating oils of a viscosity up to about 900 seconds. For heavier products such as gear lubricants, airplane engine or cylinder oils, 210 degrees Fahr., is preferred. The obvious advantage in raising the temperature of test with such products is to decrease the time element involved and expedite the actual procedure of testing.



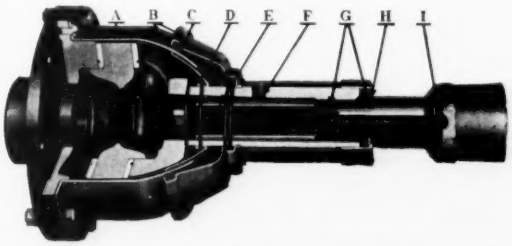
Courtesy of The Timken-Detroit Axle Company

Fig. 12—Vertical cross section through a Timken overhead worm drive. Note relative location of helical and tapered roller bearings.

So, for example, when an oil is said to have a viscosity of 500 seconds Saybolt at 100 degrees Fahr., this means that at a uniform temperature of 100 degrees Fahr., it will take 60 cc. of the oil in question 500 seconds to flow through the viscosimeter orifice.

Automotive Engine Service

Knowledge of the meaning of viscosity is of particular advantage to the bus management in meeting the operating conditions of warm weather driving, for thereby can they more intelligently select an oil which will possess adequate operating viscosity to maintain protective lubrication. A certain amount of oil consumption is necessary regardless of engine design or the grade of oil used. Where there is no apparent consumption, dilution is contributing toward maintenance of the oil level.



Courtesy of Spicer Manufacturing Corp.

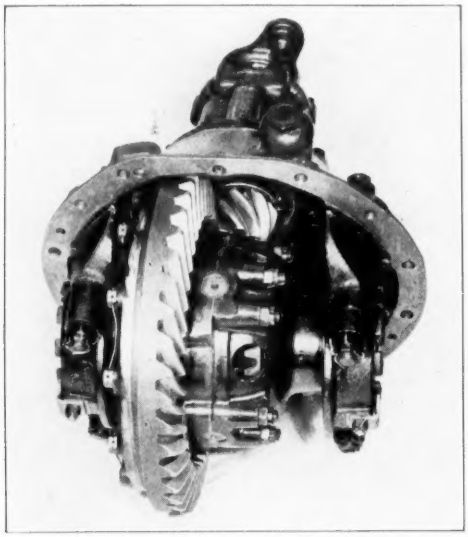
Fig. 13—Exposed view of the Spicer "1.G." universal joint. (A) gasket seal to insure against loss of lubricant; (B) inner and outer casings; (C) cork seal to prevent entry of dirt and water; (D) Spicer lubricant seal; (E) channel for lubricant; (F) point of application of lubricant; (G) and (H) means for preventing loss of lubricant, and retention of latter in spline pockets; (I) lubricant over-flow and vent.

Most automotive engines increase consumption rapidly with speed in a far greater proportion than would be expected from the speed of the engine. Also, most engines have a critical point in respect to oil viscosity and consumption under constant speed conditions,—that is, as we increase viscosity we lower consumption to a certain point. Further increase in viscosity actually increases consumption. Under these conditions use of a more viscous oil does more harm than good, especially as such oils may cause accumulation of objectionable carbon deposits.

The Society of Automotive Engineers has made marked progress in aiding in the maintenance of dependable lubrication by the adoption of a scheme of numbering motor oils according to certain viscosity ranges. This has definitely eliminated the use of such terms as light, medium, heavy, etc., according to the brand of oil involved and the respective opinion of the refiners as to the range of viscosity each term should cover. Due to lack of cooperation these terms used to cover an extremely wide viscosity range.

For this reason the Society of Automotive Engineers has standardized upon a system of grading in the interest of a more intelligent understanding of the importance of the right viscosity for any set of engine or operating

conditions. By concurrence with this system, the petroleum industry has shown its broad minded interest in cooperation, to the end that now the motorist is assured of a standardized viscosity nomenclature, irrespective of his preference in regard to brand of oil or its degree of refinement.



Courtesy of The White Company

Fig. 14—Showing the White Model 684 rear axle assembly. This is a single reduction unit with wide faced gears for low tooth pressure and durability.

The automotive manufacturers also have indicated their approval of this system of numbering by adopting it for the recommendation of engine lubricants in their instruction booklets.

The S.A.E. system is based upon numbers. The measured viscosity in seconds by the Saybolt Universal Viscosimeter is taken at 130 or 210 degrees Fahr., to provide a knowledge of the proper fluidity at average operating crankcase temperatures.

The reputation of the individual refiner must be depended upon in this regard as S.A.E. Numbers cannot be taken as a criterion of quality.

Carbon Residue*

Carbon, as an inherent component of all petroleum products, by reason of their complex hydrocarbon make-up, must remain as nearly as possible in this combined form if the products are to function effectively. Particular effort has been made by the petroleum industry to produce lubricating oils which will retain their original chemical hydrocarbon formation in actual operation.

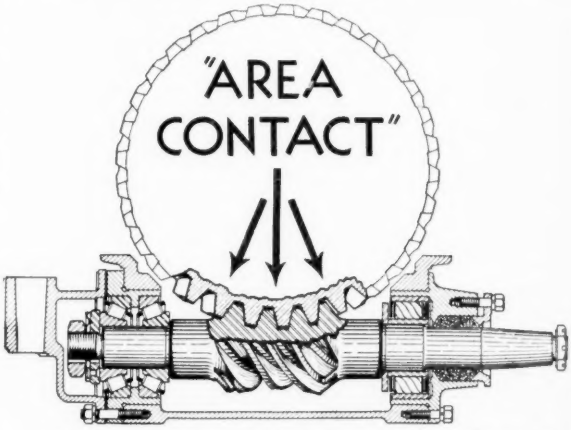
It is impossible to get away entirely from breakdown for lubricating oils, regardless of their base or nature, will develop volatile products and carbon when subjected to tempera tures considerably above the flash point. On the other hand, the extent of this reaction will depend upon the length of time the oil is exposed to such heat.

It is interesting to note that analysis of many carbon deposits has proved them to include a considerable amount of dirt, the whole being held together by gummy matter from decomposed oil, especially where the latter has been unsuited to the service involved.

Obviously, an oil having a wide range of distillation, high end point, or too great a viscosity is objectionable, inasmuch as instead of vaporizing cleanly it may undergo chemical change, as has been mentioned above, becoming sticky and collecting dirt brought in by the air.

In internal combustion engine service, carbon in its true form may develop in the cylinders in a hard mass or it may be produced in the shape of dust and pass out with the exhaust.

Inasmuch as carbon is a poor conductor of heat, when it is deposited in cylinders or around piston rings it may become heated considerably above the temperature of the cylinder walls. This condition ultimately may be hazardous if allowed to continue. Furthermore, there will be a possibility of accumulations developing on the valves and valve seats,



Courtesy of National Bearing Metals Corporation

Fig. 15—Showing the "National" underslung worm drive. This design is distinctive for the large area of contact which more evenly distributes the load and allows for positive lubrication, reduction of wear, heat and noise, and lower tooth pressures.

and in the ends of the cylinders. This may cause valves to leak, frequently resulting also in cutting of the latter and scoring of the cylinders.

In view of the fact that distilled oils, where properly refined, show the least tendency toward direct carbonization and the develop-

* For further information relative to viscosity, carbon residue and especially the interpretation of the flash and fire tests see "The Significance of Tests of Petroleum Products." Published by American Society for Testing Materials. 1934 edition.

ment of carbonaceous matter, they are generally accepted as best suited for use directly in internal combustion engine service or for blending purposes in connection with bus oils. Furthermore, any such direct carbon as may be formed through excessive use of such oils is normally of a light, fluffy nature. Carbon deposits formed from improperly refined or unsuitable oils, on the other hand, are often of a hard, flinty nature.

Flash and Fire Points*

In automotive service the motor oil must not only be capable of functioning without an undue amount of vaporization at engine crankcase temperatures, but it also must burn cleanly at those higher temperatures to which the tops of the pistons are exposed. These temperatures also prevail, but to a lesser degree at the upper sections of the cylinder walls. Here lubrication ceases to be a function on the occurrence of the explosion stroke, being re-established on the suction stroke. As a general rule, average cylinder wall temperatures are practically always below the flash point of any reputable oil.

The crankcase temperature can normally be regarded as the temperature of the engine bearings; a fair average the year round would be in the neighborhood of 130 degrees Fahr., although in warm weather, under hard driving conditions, the crankcase temperature may run higher. The figure of 130 degrees Fahr., has been chosen as the standard temperature for the determination of viscosity of oils used under the lower range of S.A.E. numbers. For higher viscosity oils, 210 degrees Fahr. has been taken as the standard.

Cylinder wall temperatures, however, will be considerably higher, the mean average being in the neighborhood of 250 degrees Fahr., at the upper parts of the cylinders. Of course, temperatures up to 300 degrees Fahr., may be encountered, but the actual matter of lubrication at such points becomes an almost negligible factor.

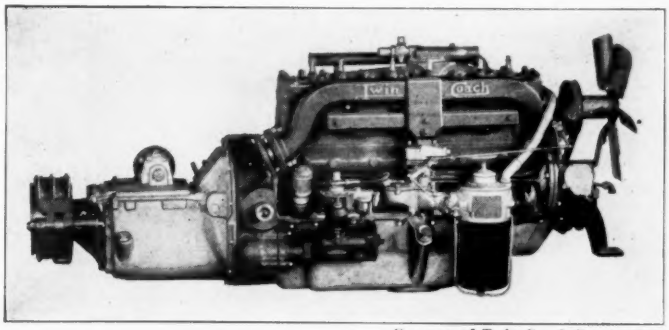
In fact, no motor oil can withstand the heat of explosion in the combustion chamber, or on the uppermost part of the piston itself; nor is lubrication actually a necessity here, due to the customary practice of locating the top piston rings somewhat below the top of the pistons. So, regardless of flash point, any motor oil which reaches the upper parts of the cylinder walls must burn. The ideal oil is that which burns as clean as possible, i.e., leaving the least amount of light fluffy carbon residue.

AUTOMOTIVE GREASE REQUIREMENTS

Grease designed for automotive service should be as free as possible from acid-forming tendencies to assure protection of the intricate surfaces of the wheel bearings, steering connections, grease-lubricated universals and shackle bolts. This calls for a grease of practically neutral reaction and one which is free from fillers or any material which may accelerate oxidation, decomposition, or the development of free acidity. In the designing of grease for bus and other types of automotive service, the most careful attention is paid, therefore, to the character and purity of the soap content, and to the viscosity of the lubricating oil used, in-as-much as this oil must do the actual work of lubrication.

This has led to the development of a distinctive type of grease, which possesses very marked advantages over the so-called cup grease; it is soft, pliable and plastic, and yet has decided non-fluid tendencies. Furthermore, it is able to form and maintain its own housing and capable of "training," or adhering both to wearing surfaces as well as itself, in much the same way that bread dough adheres and yet "strings out."

Such a grease is also resistant to heat and to centrifugal force, and yet it has no tendency to separate or break up even under the hardest kind of rough treatment. It is equally capable of lubricating the steering gear, the roller bearings of front and rear wheels, or the mechanisms of a universal joint.



Courtesy of Twin Coach Corporation

Fig. 16—Showing the carburetor side of the Twin Coach 6-cylinder engine.

It can be applied by means of pressure lubricators or by hand. It does not drip or flow under high temperatures, and it contains an oil of maximum lubricating ability, with the

* For further information relative to viscosity, carbon residue and especially the interpretation of the flash and fire tests see "The Significance of Tests of Petroleum Products," Published by American Society for Testing Materials. 1934 edition.

result that it is economical and capable of giving service for extended periods of operation.

FUNCTION OF THE MAINTENANCE DEPARTMENT

The maintenance department in a bus organization services the rolling equipment, to keep it operating efficiently and systematically. To attain real efficiency in a maintenance program, it is of the utmost importance to have this organized on a well-balanced, systematic basis. This means that all work should be performed at the proper time. Performance of unnecessary work is equally as wasteful as neglecting to make necessary repairs. For this reason, bus companies have prepared time studies on this subject, and a good deal of progress has been made during the last few years which has resulted in real savings and added reliability and safety.

Bus manufacturers and the petroleum industry appreciate thoroughly the hearty cooperation which they have enjoyed from maintenance departments throughout the country; this has permitted them to become thoroughly familiar with the problems of the bus operator, which has been to their distinct advantage in this work of attaining satisfactory performance of their materials.

The importance of the maintenance department is fully recognized by progressive bus managements, and final selection of new equipment or products is generally based on the recommendations of the head of that department. No other department is better qualified to assist the management in this task, because any deficiency in either equipment or lubricants is promptly brought to the attention of the head of this department, either directly through out-right failure, or through excessive costs as shown in the maintenance records.

Experience has proved it to be of the utmost importance that the right type of equipment is used because, regardless of how great the effort to operate efficiently, the results will be otherwise unsatisfactory and the costs excessive. In connection with this many companies have standardized on certain definite types of equipment, and keep a well balanced stock of spare parts for their particular needs. This eliminates waiting for parts and unnecessary tie-ups, and allows them to operate with a minimum of stand-by equipment.

The maintenance department also cooperates very closely with the traffic department in working out schedules, to make certain that these are not set too fast for safety, and that no undue hardship is imposed on the equipment. The supervision of drivers is handled by the operating department, but a careful check is also maintained by the maintenance department for the safeguarding of the equipment from reckless handling.

Maintenance schedules in modern bus transportation systems are set up on a preventative basis, to eliminate breakdowns and road failures as much as possible. In this connection records are kept to establish the useful life of virtually every part of the equipment, and a comfortable margin of safety is allowed for replacement of the parts involved. Also in this connection, one of the most important duties of the maintenance department is the keeping of inventory and disbursement records of petroleum products. It is through these records that a check is kept on the mechanical condition of each bus between regular inspection periods. Gasoline and oil consumption figures are always a good barometer of the mechanical condition of the bus, and any fluctuation in either gasoline or oil consumption is a sure indication of some mechanical defect in the equipment.

In view of the fact that these defects may occur at any time, it is essential to work out gasoline and oil economy figures for each bus daily, to enable detection of possible defects and to prevent the vehicle from being sent out on another trip without complete information as to the cause of this fluctuation. If this practice is followed out carefully, it will help materially to reduce breakdowns, road failures and assure lowest maintenance and operating costs.

Printed in U. S. A. by
EDGAR C. RUWE CO., INC.
72 Washington St., N. Y. C.